Topological superconductivity and topological quantum computation

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Abstract

Symmetry and topology are key to understanding material properties. Topology in condensed matter physics has a long history – it has played a crucial role in the classification of topological defects in condensed matter systems, namely, nontrivial textures in real-space configurations. The integer quantum Hall effect discovered in 1980 is a first example of a two-dimensional topological insulator (TI) phase, where topological nontriviality is realised in the Hilbert space of quantum states. Since the first theoretical prediction of three-dimensional TIs and their subsequent experimental discovery a decade ago, there has been a burst of theoretical and experimental activities in the new and rapidly growing field of topological insulators and superconductors.

One of the significant consequences of topological superconductivity is that Majorana fermions can emerge as elementary excitations. Majorana fermions – charge-neutral particles which are their own antiparticles – have long been sought after in the area of high-energy physics, yet its detection as an elementary particle remains elusive to this day. Majorana fermions are protected by topology inherent in the system and obey non-Abelian statistics, opening the door to new and powerful methods for quantum information processing. Thus, creating and controlling Majorana fermions in condensed matter systems will not only be a breakthrough in fundamental physics, but also potentially lead to realisation of scalable, fault-tolerant topological quantum computation. In this talk, I will introduce the concept of topology governing material properties and discuss how Majorana fermions can be utilised for quantum computation.